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Strength and microstructure properties of spent coffee grounds stabilized with rice husk ash and slag geopolymers

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HIGHLIGHTS

- Possibility of using waste materials as recycled pavement construction materials.
- Explained role of curing time on compressive strength of coffee ground geopolymers.
- Long term microstructure development was examined via scanning electron microscope.

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ABSTRACT

This paper investigates the strength and microstructure properties of spent coffee grounds stabilized with rice husk ash and slag geopolymers to produce a green construction subgrade material. Spent coffee grounds (CG) and rice husk ash (RHA) are organic wastes derived from agricultural products. CG is the residue from ground coffee beans. RHA is a by-product from the burning rice husk used to generate electricity. Ground granulated blast furnace slag (S) is a waste by-product derived from steel production. RHA and S were used as geopolymeric precursors (P). This study provides an insight on the long-term strength performance and microstructural formation of geopolymers synthesized from agricultural waste products. The influence factors studied were liquid alkaline activator content (L), RHA content, S content, temperature and curing time. By observing the strength development of CG-RHA geopolymers for up to 90 days, it was found that elevated temperature curing was needed for these CG:RHA geopolymers to develop long-term strengths. Test results show that an optimum mix of CG:RHA:S 70:20:10 cured at 50 °C can achieve an Unconfined Compressive Strength (UCS) of 2 MPa after 90 days of curing. The outcome of this research will enable CG, S and RHA waste products to be used as sustainable materials in pavement applications.

1. Introduction

Current advancements in civil engineering technology has enabled rapid global urbanization and the overall improvement in lifestyles. However, many current construction technologies and methods rely on extraction of natural and non-renewable resources such as quarry materials for embankment construction. An embankment structural fill material is a tested material used to build a strong and stable road subgrade. However, the in-situ soil at a site may be too weak to support a structure. Therefore, the in-situ soil needs improvements to provide the required structural capacity. Conventional stabilization methods used Lime and Portland cement. However, the use of Portland cement, a major component used in contemporary construction, is alarmingly energy intensive [1] and its manufacture creates a large carbon footprint [2], which contributes to global warming. As a result, the concept of sustainable development has been rapidly introduced in the adoption of recycled materials in civil engineering construction Fig. 2.

Research aimed at reuse of wastes in construction applications stems from the need to reduce the quarrying of virgin construction materials such as granite, limestone and rhyollite. The concept

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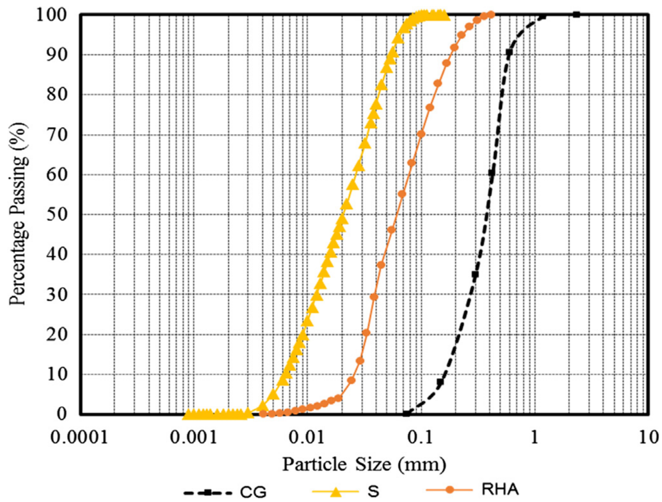

Fig. 1. Grain size distribution of CG, RHA and S.

behind reuse of recycled construction materials is to collect the residue from the demolition of existing infrastructures, such as buildings and road pavements, and then reprocess or reconstitute these waste materials to form usable construction materials. Recycled concrete aggregates [3,4], recycled glass [5–12], crushed brick [13,14], and reclaimed asphalt pavement [15,16] are among the many construction and demolition materials currently being studied as green construction materials. The successful utilization of these materials would not only prove to be highly economical, because waste materials with no value would be converted to construction materials, but also highly environmental-friendly given the minimization in the need for natural resources and landfill space (see Fig. 1).

Geopolymeric binders are garnering attention in the construction industry because it possesses similar cementitious properties to hydrated Portland cement. Geopolymers were originally developed as a fire retardant, but has since been applied in the construction industry due to its high compressive strength and virtually carbon-neutral characteristic compared to Portland cement. Geopolymers can be synthesized by introducing parent materials containing high levels of alumino-silicate, termed as precursors, to a highly-alkaline liquid. The mixture undergoes a process known as alkaline activation in which the alumino-silicate compounds break down and form calcium silicate hydrate (CSH) or calcium aluminosilicate hydrate (CASH) and sodium aluminosilicate hydrate (NASH) gels [17–19]. Precursors which have been studied include fly ash, a waste material derived from coal-combustion and slag, an industrial waste resulting from refining iron ores. Sodium hydroxide (NaOH) is commonly used as the alkaline activator liquid to produce geopolymers.

While the concept of geopolymerization has existed since the late 1900s, many geopolymeric materials are highly experimental, hence many contractors are still not confident in the performance of geopolymers due to the organic nature of some precursors. Nevertheless, studies have shown that geopolymer-stabilized soils possesses improved strength and stiffness, which implies that geopolymerization can be effective as an alternative soil-stabilization method, hence reducing the reliance towards traditional stabilizers such as cement and lime. Novel studies have been undertaken recently to stabilize highly organic wastes, such as water treatment sludge [20–23], marginal lateritic soil [24,25] and soft clay [26] to produce geopolymers with considerable strength. In the future, the geopolymer may be applied to improve traditional ground improvement methods, such as deep mixing,

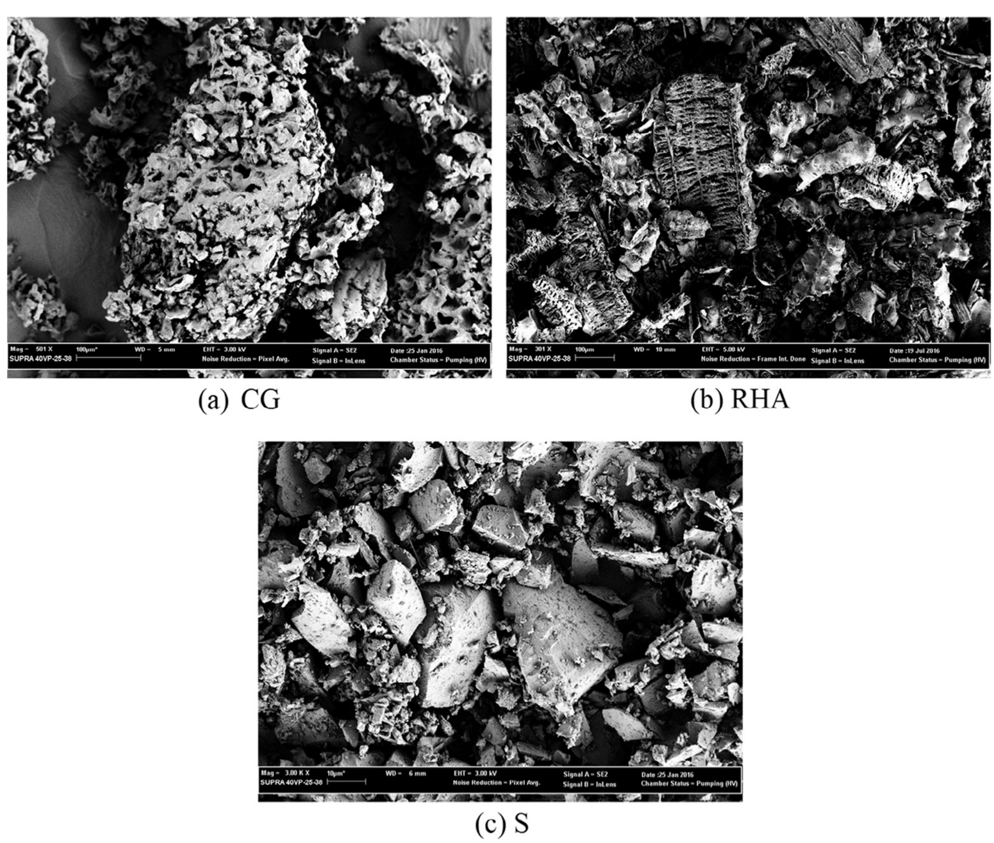

Fig. 2. SEM images of: (a) CG, (b) RHA and (c) S.